

Standard Test Method for Tensile Strength of Hydraulic Cement Mortars

1. Scope

1.1 This test method covers the determination of the tensile strength of hydraulic cement mortar employing the briquet specimen. It is primarily for use by those interested in research on methods for determining tensile strength of hydraulic cement.

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport address all of the safety problems associated with its use. It is the responsibility of however uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Applicable Documents

2.1 ASTM Standards:

C 150 Specification for Portland Cement

C 184 Test Method for Fineness of Hydraulic Cement by the 150- μm (No. 100) and 75- μm (No. 200) Sieves

C 187 Test Method for Normal Consistency of Hydraulic Cement

C 670 Practice for Preparing Precision Statements for Test Methods for Construction Materials

C 778 Specification for Standard Sand

C 1005 Specification for Weights and Weighing Devices for Use in the Physical Testing of Hydraulic Cements

E 11 Specification for Wire-Cloth Sieves for Testing Purposes

3. Significance and Use

3.1 Researchers in the field of hydraulic cement have recognized the need for improved tensile strength. This test method allows for the determination of tensile strength of a hydraulic cement mortar by casting and testing briquet specimens. It is recommended that the tester be familiar with this test method in order to obtain the best possible accuracy and precision.

3.2 Table 2 contains minimum tensile strength values, which were stated limits in Specification C 150-68. The user of this test method may be interested in comparing research results with these values when briquets composed of 1 part cement to 3 parts standard sand have been made. These values may not be appropriate for comparison when different proportions, or proportions involving other than standard sand have been used.

4. Apparatus

4.1 *Heights and Weighing Devices*—The weights and weighing devices shall conform to the requirements of Specification C 1005. The weighing device shall be evaluated for precision and accuracy at a total load of 1000 g or at 2000 g, as applicable.

4.2 *Sieves*—Square-hole woven wire cloth, No. 20 (850- μ m) and No. 30 (600- μ m) sieves conforming to Specification E 11 shall be used.

4.3 *Glass Graduates*—Glass graduates of suitable capacities (preferably large enough to measure the mixing water in a single operation) shall be made to deliver the indicated volume at 68 °F (20 °C). The permissible variation shall be ± 1.0 mL. These graduates shall be subdivided to at least 1 mL, except that the graduation lines may be omitted for the lowest 5 mL for 100 and 150-mL graduates and for the lowest 10 mL for a 200-mL graduate. The main graduation lines shall be circles and shall be numbered. The least graduation lines shall extend at least one seventh of the way around the cylinder, and intermediate graduations shall extend at least one fifth of the way around.

4.4 *Briquet Molds*—The molds for making test specimens shall be made of metal not attacked by the cement mortar, and shall have sufficient material in the sides to prevent spreading during molding. Gang molds, when used, shall be of the type shown in Fig. 1. The dimensions of the briquet molds shall conform to the following requirements: width of mold, between inside faces, at waist line of briquet, 1 in. (25 mm) with permissible variations of ± 0.01 in. (0.25 mm) for molds in use and ± 0.005 in. (0.13 mm) for new molds; thickness of molds measured at the point of greatest thickness on either side of the mold at the waist line, 1 in. with permissible variations of $+0.004$ in. (0.10 mm) and -0.002 in. (0.05 mm) for new molds and -0.02 in. (0.5 mm) for molds in use. The briquet test specimens shall conform to the dimensional requirements shown in Fig. 2.

4.5 *Trowel*—The trowel shall be of a convenient size and have a steel blade 4 to 6 in. (100 to 150 mm) long.

4.6 *Testing Machine*—The testing machine shall be capable of applying the load continuously at a rate of 600 ± 25 lbf (2.67 ± 0.11 kN)/min, with provision for adjustments of the rate of loading. The requirements for accuracy of the testing machine shall be as follows: The error for loads of not less than 100 lbf (445 N) shall not exceed ± 25 % for a new machine, or 1.5 % for a used machine. The testing machine shall be calibrated frequently in order to determine its accuracy.

NOTE 1—For instructions relating to the manner and frequency of calibration of the testing machine, see Section 40 of the Manual of Cement Testing.

4.7 *Clips*—The clips for holding the tension test specimens shall be in accordance with Fig. 3.

5. Standard Sand

5.1 The sand used for making test specimens (see 8.1) shall be natural silica sand conforming to the requirements for 20-30 standard sand as described in Specification C 788.

6. Temperature and Humidity

6.1 The temperature of the air in the vicinity of the mixing slab, the dry materials, molds, and base plates shall be maintained between 68 and 81.5 °F (20 and 27.5 °C). The temperature of the mixing water, moist closet or moist room, and water in the briquet storage tank shall not vary from 73.4 °F (23 °C) by more than ± 3 °F (1.7 °C).

6.2 The relative humidity of the laboratory shall not be less than 50 %. The moist closet or moist room shall be so constructed as to provide storage facilities for test specimens at a relative humidity of not less than 95 %.

7. Number of Briquets

7.1 Three or more briquets shall be made for each period of test specified.

8. Procedure

8.1 *Proportioning, Consistency, and Mixing of Mortars:*

8.1.1 The proportions of the standard mortar shall be 1 part cement to 3 parts standard sand by weight. The quantities of dry materials to be mixed at one time in the batch of mortar shall be not less than 1000 nor more than 1200 g for making six briquets and not less than 1500 g nor more than 1800 g for making nine briquets. The percentage of water used in the standard mortar shall depend upon the percentage of water required to produce a neat cement paste of normal consistency from the same sample of cement and shall be as indicated in Table 1, the values being in percentage of the combined dry weights of the cement and standard sand. Determine the percentage of water required to produce a neat cement paste of normal consistency in accordance with Test Method C 187.

NOTE 2—Other proportions involving the use of graded sand, silica flour, or other similar materials may also be used to develop meaningful research information.

8.1.2 Weigh the dry materials, place them upon a smooth nonabsorbent surface, thoroughly mix dry, and form a crater in the center. Pour the proper percentage of clean water into the crater, and turn the material on the outer edge into the crater within 30 s by the aid of a trowel. After an additional interval of 30 s for the absorption of the water, during which interval lightly trowel the dry mortar around the outside of the cone over the remaining mortar to reduce the evaporation losses and to promote absorption, complete the operation by continuous, vigorous mixing, squeezing, and kneading with the hands for 1-1/2 min. During the operation of mixing, protect the hands with snug-fitting rubber gloves.

8.2 *Molding Test Specimens:*

8.2.1 Before being filled, thinly cover the molds with a film of mineral oil. Immediately following completion of mixing the mortar, and with the molds resting on unoiled glass or metal plates, fill the molds heaping full without compacting. Then press the mortar in firmly with the thumbs, applying the force 12 times to each briquet, at points to include the entire surface. The force shall be such that the simultaneous application of both thumbs will register a force of 15 to 20 lbf (67 to 89 N). Maintain each application of the thumbs not longer than sufficient to attain the specified force. Then heap the mortar above the mold and smooth it off with a trowel. Draw the trowel over the mold in such a manner as to exert a force of not more than 4 lbf (17.8 N). Cover the mold with a plane glass or metal plate oiled with mineral oil, and turn over the mold and plates (held together with the hands) rotating the mold about its longitudinal axis. Remove the top plate and repeat the operation of heaping, thumbing, and smoothing off. Use no ramming or tamping, nor any troweling in excess of that required to smooth off the specimen.

8.3 *Storage of Test Specimens:*

8.3.1 Keep all test specimens, immediately after molding, in the molds on the base plates in the moist closet or moist room for from 20 to 24 h with their upper surfaces exposed to the moist air but protected from dripping water. If removed from the molds before 24 h, keep them on the shelves of the moist closet or moist room until they are 24 h old, then immerse the specimens, except those for the 24-h test, in saturated lime water in storage tanks constructed of noncorroding materials. Keep the storage water clean by changing as required.

8.4 *Determination of Tensile Strength:*

8.4.1 Test the briquet specimens immediately after their removal from the moist closet for 24-h specimens, and from storage water for all other specimens. Break all test specimens for a given test age within the permissible tolerance pre. scribed in the following table:

Test Age	Permissible Tolerance
24 h	$\pm 1/2$ h
3 days	± 1 h
7 days	± 3 h
28 days	± 12 h

If more than one specimen at a time is removed from the moist closet for the 24-h tests, cover these briquets with a damp cloth until time of testing. If more than one specimen at a time is removed from the storage water for testing, place these briquets in a pan of water at a temperature of 73.4 ± 3 °F (23 ± 1.7 °C) and of sufficient depth to completely immerse each briquet until time of testing.

8.4.2 Wipe each briquet to a surface-dry condition, and remove any loose sand grains or incrustations from the surfaces that will be in contact with the clips of the testing machine. The bearing surfaces of the clips shall be clean and free of sand, and the roller bearings shall be well oiled and maintained so as to ensure freedom of turning. Keep the stirrups supporting the clip free of accumulations, and keep the pivots in proper adjustment so that the clips may swing freely on the pivots without binding in the stirrups. Carefully center the briquets in the clips and apply the load continuously at the rate of 600 ± 25 lbf (2.67 ± 0.11 kN)/min.

9. Faulty Briquets and Retests

9.1 Briquets that are manifestly faulty, or that give strengths differing by more than 15 % from the average value of all test briquets made from the same sample and tested at the same period, shall not be considered in determining the tensile strength (Note 3). After discarding briquets or strength values, if less than two strength values are left for determining the tensile strength at any given period, a retest shall be made.

NOTE 3—Reliable strength results depend upon careful observance of all of the specified requirements and procedures. Erratic results at a given test period indicate that some of the requirements and procedures have not been carefully observed; for example, those covering the testing of the briquets, as prescribed in 8.4.2.

10. Calculation

10.1 Record the total maximum load indicated by the testing machine and calculates the tensile strength in pounds-force per Square inch or kilopascals. If the cross-sectional area of a briquet varies more than 2.0 % from the nominal, use the actual area for the calculation of the tensile strength. The tensile strength of all acceptable test briquets (see Section 9) made from the same sample and tested at the same period shall be averaged and reported to the nearest 5 psi (34.5 kPa).

11. Precision and Bias

11.1 The following precision statements are applicable when a test result is the average of tensile strength tests of three briquettes molded from a single batch of mortar tested at the same age. It is applicable to mortar made with Type I, IA, II, or III cement tested at 3 or 7 days (1 and 3 days for Type III cement) (Note 4).

NOTE 4—The appropriate limits are likely somewhat smaller at 1 day and larger at ages greater than 7 days.

11.1.1 *Multilaboratory Precision*—The multilaboratory standard deviation has been found to be 32 psi (220.6 kPa). Therefore the results of properly conducted tests of a single batch by two different laboratories should not differ from each other by more than 90 psi (620.5 kPa) (Note 5).

NOTE 5—These numbers present, respectively, the (IS) and (D2S) limits as described in Practice C 670.

11.1.2 *Single-Laboratory Precision*—The single-laboratory standard deviation has been found to be 21 psi (144.7 kPa). Therefore the results of two properly conducted tests of single batches of mortar made with the same materials either on the same day or within the same week should not differ from each other by more than 59 psi (406.7 kPa) (Note 5).

For additional useful information on details of cement test methods, reference may be made to the “Manual of Cement Testing,” *Annual Book of ASTM Standards*, Vol 04.01.

Table 1 Percentage of Water for Standard Mortars

Water for Neat Cement Paste of Normal Consistency, %	Water for Mortar of One Part Cement to Three Parts Standard Sand, %^A
15	9.0
16	9.2
17	9.3
18	9.5
19	9.7
20	9.8
21	10.0
22	10.2
23	10.3
24	10.5
25	10.7
26	10.8
27	11.0
28	11.2
29	11.3
30	11.5

^A When the proportions of cement to sand are other than one to three by weight, the amount of mixing water shall be calculated from the following formula, upon which Table 1 is based:

$$y = 2/3 [(P/(n+1))] + K$$

where:

y = water required for the sand mortar, %,

P = water required for neat cement paste of normal consistency, %

n = number of parts of sand to one of cement by weight, and

K = a constant which for the standard sand has the value 6.5.

Table 2 Tensile Strength^A

	Cement Type				
	I	II	III	IV	V
1 day in moist air, psi (kPa)	275 (1896)
1 day in moist air, 2 days in water, psi (kPa)	150 (1034)	125 (862)	375 (2586)
1 day in moist air, 6 days in water, psi (kPa)	275 (1896)	250 (1724)	. . .	75 (1207)	250 (1724)
1 day in moist air, 27 days in water, psi (kPa)	350 (2413)	325 (2241)	. . .	300 (2068)	325 (2241)

^A Taken from Specification C 150 - 58 without change.

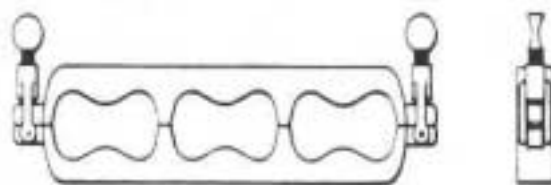


Fig. 1. Briquet Gang Mold

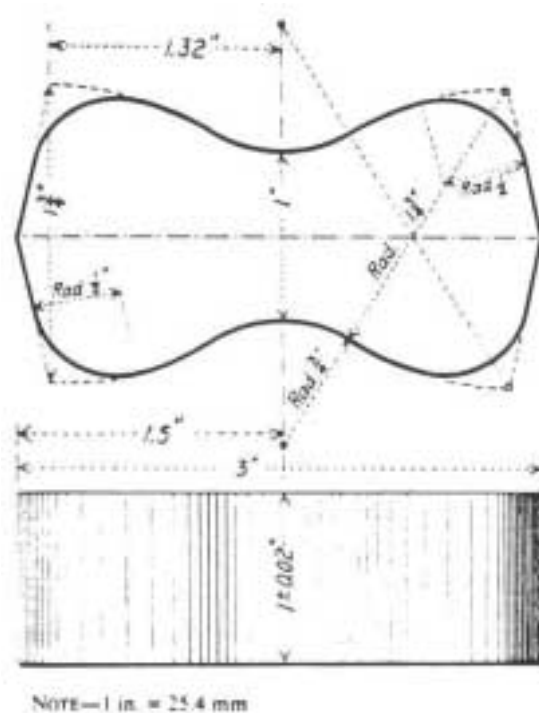


Fig. 2. Briquet Specimen for Tensile Strength Test

